2.1.1 Annual highlights

The brightest galaxies at cosmic dawn

Last year, the astronomical community found itself in a bit of a crisis, after the James Webb Space Telescope almost immediately had revealed a large number of galaxies that were seemingly too big, bright, and abundant than virtually all cosmological models predicted. How these early galaxies were able to form such an enormous amount of stars in so little time is not only puzzling, but had people doubt everything from instruments, to observational techniques, to analyses, and even the "standard" model of structure formation in the Universe.

Rather than overthrowing the fundamentals of cosmology, the solution to the puzzle is likely a combination of several mechanisms. But a crucial factor was shown by Mason et al. (2023a) from "first principles", i.e. as a theoretical calculation with few assumptions beyond what is well-established:

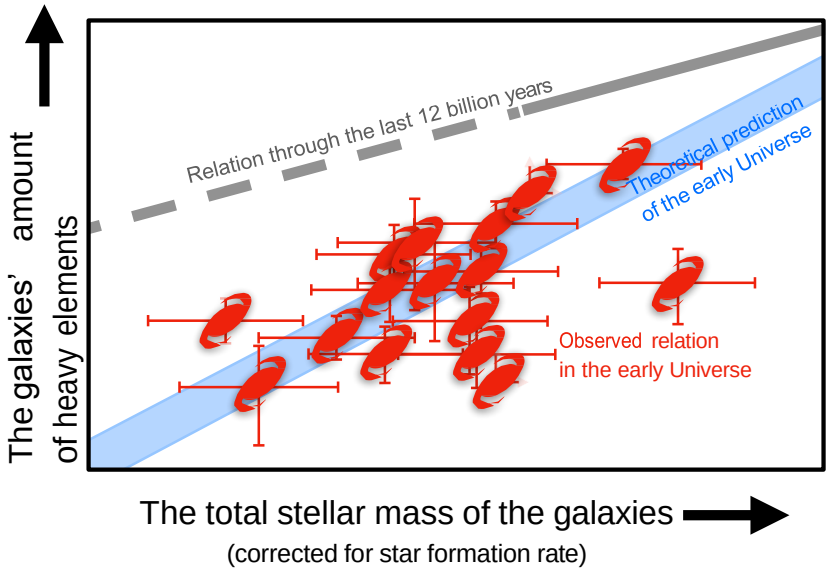
During their very first epochs of star formation, galaxies form stars in rapid bursts and undergo particularly bright phases as the most massive and luminous stars are still alive and the galaxies are unobscured by the dust that is formed later. For a brief period, only a few percent of the age of the Universe at that time, galaxies therefore appear extraordinarily bright. And it is these galaxies that we now see.

Before there were building blocks

Of all the elements that comprise the visible world, only the three lightest were present when the Universe was born. All heavier elements — from the carbon that comprises all known life, to the oxygen you breathe, to the gold ring on your finger — were created by stars much later.

Throughout most of the history of the Universe, galaxies apparently have quickly reached an equilibrium between their amount and production of stars, and their content of heavy elements. But galaxies don't form instantaneously, and if we look far enough back in time, we should theoretically be able to see more "pristine" galaxies, before they were polluted by heavy elements.

This theory was confirmed last year when Heintz et al. (2023d) examined the chemical composition of 16 galaxies, seen 500–800 million years after the Big Bang, finding them all to be significantly poorer in heavy elements than later galaxies. This discovery, which would have been impossible before we had James Webb, confirms our understanding of the early formation and evolution of galaxies.



This diagram shows the relation between galaxies' production of stars, and their amount of heavy elements. Whereas the gray line shows the relation throughout most of the history of the Universe, the red points shows the recent observation of the early Universe. They fit nicely with theoretical predictions from computer simulations (the blue band).